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November 19, 2002

To: Rulemaking File
Rulemaking Reference Number R-02-04
Mercury Waste Classification and Management

Subject: External Scientific Peer Review Report
University of California, Santa Cruz

Attached is the external scientific peer review report concerning the scientific bases for the Mercury Waste Classification and Management regulations that was performed by the University of California, Santa Cruz, in accordance to the requirements in Health and Safety Code section 57004, subdivision (d). The Mercury Report (August 2002), which contained the scientific basis, was reviewed by:

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Sections 1, 2, 3 and 5 of the Mercury Report, which was finalized in August 2002, contain the scientific bases for the regulations. Pursuant to Health and Safety Code section 57004, subdivision (d), the Department of Toxic Substances Control requested the reviewer to review and comment on Sections 1, 2, 3, and 5 of the Mercury Report (August 2002). Dr. Flegal has provided comments on the four relevant sections satisfying the requirement for an evaluation of the scientific basis for the regulations in accordance with Health and Safety Code section 57004, subdivision (d).

REVIEW OF THE DEPARTMENT OF TOXIC SUBSTANCES CONTROL MERCURY REPORT

November 7, 2002

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SUMMARY

The Department of Toxic Substances Control (DTSC, 2002) *Mercury Report* represents a substantial effort to synthesize the existing information on mercury's chemistry, toxicity, sources of contamination, and present options to reduce that contamination in California. By necessity, the report relies extensively on published and unpublished "gray literature" reports on those various considerations to derive a proposed recommendation to "regulate as hazardous wastes, consumer products with intentionally added mercury." That proposal is predicated upon extensively documented scientific evidence that (a) "mercury is a toxic, persistent, and bioaccumulative chemical substance" and that (b) there are substantial, on-going releases of industrial mercury through the consumption of consumer products in California.

Both of those predications have been affirmed at the national and international levels by numerous studies. The most notable among these are summarized and cited in the recent reports of the National Research Council (NRC, 2000), United States Environmental Protection Agency (U.S. EPA, 1997), and the United States Geological Survey (Sznopek and Goonan, 2000). Data and conclusions from each of those three reports are repeatedly cited in the *Mercury Report*. Consequently, the proposed *Mercury Report* recommendation to "list added mercury-containing consumer products that can be

recycled or have a non-mercury alternative as a hazardous waste when discarded" is based on a large body of rigorously critiqued reports and articles in peer-reviewed scientific journals and their equivalents (e.g., United States Geological Survey reports).

However, the *Mercury Report* provides limited information on the extent and potential effects of mercury contamination within the State of California. That information is primarily derived from (a) simple, linear extrapolations from the national data, using the ratio of the California populace to that of the nation and (b) data from the "gray literature". The former oversimplifies the complexity of the mercury problem in California, where much of that contamination is from the historic legacy of mercury mining and the extraction of gold with mercury amalgams that occurred over the past 150 years. The latter lacks the creditability of peer-reviewed scientific publications, and do little to strengthen the scientific rationale for the DTSC's proposed regulatory concept.

Both of those limitations could be addressed with a more extensive synthesis of peer-reviewed reports on the extent of mercury contamination in California. These include numerous studies in scientific journals and their equivalents that specifically address natural or baseline concentrations of mercury and quantify the magnitude of industrial mercury contamination in the state. Those data, coupled with unpublished—but well documented—databases compiled by federal, state, regional, and local agencies and other organizations in California would provide a much more compelling rationale for the DTSC's proposed regulatory concept.

The existing rationale in the *Mercury Report* is also compromised by numerous statements that are either circumspect or simply incorrect. These deficiencies are attributed to the difficult task in preparing a report that, although 125 pages long, needs to be terse and readable to a diverse audience. (I have encountered the same difficulties in preparing this assessment of the report.) Still, a report that acknowledges 20 individuals for their "contribution and assistance in ideas, research, development, and review of this report" should evidence that editing.

In spite of these criticisms, the *Mercury Report* has accomplished its objectives of synthesizing existing scientific information on the magnitude of mercury contamination and the potentially adverse effects of that contamination in California to substantiate their proposed mercury regulations. Mercury is a "toxic, persistent, bioaccumulative chemical substance"; and it is a pervasive contaminant in the State of California, where the historic legacy of massive industrial mercury contamination extends over one and one-half centuries. Reasoned regulatory actions to limit additional mercury contamination in the state are, therefore, justified by the extensive scientific literature on mercury contamination and toxicity.

TASK ORDER FOR THE REVIEW

As delineated in Interagency Management Agreement No. 98-004-TO-(#), the task order to the University of California from the Department of Toxic Substances Control (DTSC) was to provide a written scientific peer review on the scientific basis of DTSC's proposed regulations of consumer products with intentionally added mercury as hazardous wastes, as specified in their staff document, *Mercury Report*. The task order notes that "the scientific basis of the proposed regulations is that mercury is a toxic, persistent, and bioaccumulative chemical substance and in order to further control environmental releases, regulations to encourage pollution prevention (recycling and resource reduction) are needed." The task order then states that "DTSC's proposed regulations are to regulate as hazardous wastes, consumer products with intentionally added mercury."

The task order specifies a written peer review of 4 of the 6 sections of the DTSC *Mercury Report*. These sections (1,2,3 & 5) "provide the scientific basis of the DTSC's proposed regulatory concept for mercury to:

> (1) list intentionally added mercury-containing consumer products that can be recycled or have a non-mercury alternative as a hazardous waste when discarded."

The other two sections of the *Mercury Report* are Section 4, which "contains a list of mercury containing products and alternatives", and Section 6, which "contains the DTSC's recommendations to prevent waste-derived sources of mercury from entering the environment".

The DTSC report acknowledges that there is some argument about whether or not landfills even represent a significant source to the environment, but indicates the regulations will be considered regardless of the promise of any significant benefit or cost to consumers. The regulations, it seems, will proceed regardless of a qualitative understanding of the potential impacts or benefits. Under some paradigms of thought, this could be considered poor science and poor policy, but the benefits of a proactive response towards low-level concentrations of heavy metals have been demonstrated for other elements (e.g., lead)

Regardless, the DTSC has undertaken a massive effort to compile their mercury report, which includes a great deal of data. From a scientific standpoint, it is perhaps best to evaluate the report on its efforts to link the well-know characteristics of mercury (toxicity, pervasive, bioaccumulative) to the disposal of waste and the implementation of the DTSC's proposed regulations. Ideally, the report should provide appropriate scientific background for their proposal and address the following points and questions:

Toxic: Cite any evidence for low level chronic exposure in California (i.e., demonstrate that mercury a public health issue within the state). Are there relevant epidemiological studies cited? Is there evidence of the toxic effects of mercury to other organisms in California? Will the proposed regulations be important in reducing environmental

exposure to mercury in the state? How do different types of landfills affect the mobility of mercury and environmental exposure in the state?

Persistent: How do the proposed regulations affect the persistence of mercury in the California environment? How will the proposed regulations promote or discourage the extraction of mercury from the lithosphere to the biosphere within the state? Again, how do different types of landfill affect the mobility of mercury in the state's environment? How should mercury contaminated material be dealt with at a landfill in the state?

Bioaccumulative: How will the proposed regulations affect the bioaccumulation of mercury in the state's biosphere? Do the chemical transformations of mercury in a landfill make it more of less available for bioaccumulation within the state? How would the chemical transformations of organic and inorganic mercury species differ in different types of landfills in California?

Although it is relatively easy to address some of theses questions, such as describing studies on the low-level chronic toxicity of mercury, it is difficult to address other questions, such as the importance of chemical transformations of mercury in landfills, for which the answers are largely unknown. Those qualifications are apparent in the following assessment of the four sections of the DTSC report.

Section 1: Nature and Extent of California's Mercury Contamination: A Summary

In spite of this section's title, it contains limited information on either the sources of mercury contamination or the magnitude of mercury contamination within California. For example, Subsection I-II.A, *Background Mercury Levels*, summarizes two reports on mercury levels in soils for the entire United States (U.S. EPA, 1997) and for the world (Andersson, 1979). The former states that soils in the United States typically contain between 8 and 117 ng/g and the latter states that the "normal range of 10–50 ng/g seems to be reasonable for soil parent material, but much higher levels may be found in certain areas." Notably, many of those areas are in California, where large mercury deposits made it the principal source of mercury in North America. Among these areas is the New Almaden Quicksilver mining district, which is in the Santa Clara Valley and drains to the Guadalupe River watershed; and was, historically, North America's largest producer of mercury, yielding 37 million kg between 1845 and 1975 (Cargill et al., 1980).

Consequently, both the geology of California and the impact of its mercury mining activities should be specifically addressed in any assessment of the nature and extent of mercury contamination in the state. This could be accomplished through a synthesis of reports on the natural sources of mercury and the mining of mercury in California. Such reports are being conducted by, among others, the USGS (http://minerals.usgs.gov/mercury/hg_science_activities.pdf). These include numerous USGS reports (e.g., Alpers, C.N. and Hunerlach, M.P., 2000) and peer reviewed articles in scientific journals (Domagalski, 1998; 2001). [One such USGS report, Rytuba and Kleinkopf (1995), is cited in a latter subsection on tailings dumps (I-D-2) of the *Mercury*

Report.] In addition, there have been a large number of studies by the Central Valley and San Francisco Bay Regional Water Quality Control Boards, and associated programs (e.g., San Francisco Bay Regional Monitoring Program) that have produced a substantial amount of data on baseline and elevated levels of mercury in California waters, sediments, and organisms. With all of those resources, the DTSC is in a position to compile a much more thorough, quantitative assessment of the extent of mercury contamination in California to substantiate their proposal to regulate wastes containing elevated levels of mercury.

The subsequent assessment of landfill deposition of mercury (I-II-C) is, similarly, based on national studies by the United States Geological Survey (USGS, 2000) and the United States Environmental Protection Agency (U.S. EPA, 1997). Data from the two studies are normalized to estimate landfill depositions in California, by using the ratio of the California populace to that of the United States. Although this approach may appear overly simplistic, it provides a reasonable first order approximation of the landfill deposition of mercury in California, assuming there are no data for California. However, such estimates should not be reported to three significant figures (e.g., 17.3 tons), which indicate a greater level of information than the first order estimates justify.

There do appear to be some data on the leaching of mercury from landfills and mercury contaminated sites in California in the following subsections (1-II-C and 1-II-D, respectively). The former are reportedly in the Waste Management Unit Database System (WMUDS), which is cited in the subsection, *Leaching of Mercury from Landfills*; and the latter are in the DTSC's Site Mitigation Program (CalSites), which is cited in the following subsection, *Mercury Contaminated Sites in California*. A reference for the former (Frampton, 1998), but not the latter, was provided in the *Mercury Report.* Although neither data sets were readily accessible within the limited time (~2 weeks) available to review the *Mercury Report*, those data sets would appear to be of substantial value in quantifying the nature and extent of California's mercury contamination and should be highlighted and fully referenced in the *Mercury Report*.

There also is an extensive data set on mercury in California's air, which is referenced as a California Air Resources Board (ARB) web site in the following subsection (I-III) (www.arb.ca.gov/aqd/toxics/statepages/hgstate.html). However, the *Mercury Report* notes that "median ambient air concentrations reported at this web site do not reflect elevated air concentrations that may occur near stationary sources of mercury emissions." Because this would include the waste disposal sites that the *Mercury Report* is designed to address, the value of the averaged values in the ARB for the DTSC study is limited. However, the original data, including elevated atmospheric mercury concentrations may be available through the Air Toxics "Hot Spots" Program (AB 2588) that is also referenced in his section; and those data may substantiate the DTSC proposal.

The remainder of the first section provides an abbreviated summary of state and federal standards and goals for mercury exposure in air and water, as well as an Office of Environmental Health Hazard Assessment (OEHHA) tabulation of sport fisheries advisories for mercury contaminated water bodies in California (OEHHA, 1999). These

specifics provide some of the information needed to quantify the magnitude of mercury contamination in California that was absent in the first part of the section.

Some specifics:

Page 1. “Because metallic mercury is a liquid at room temperature, it is especially mobile in the environment.” This is a misstatement. One does not follow the other. Mercury is mobile in the environment because of its complex biogeochemical behavior, not because of the physical properties of the native element at room temperature.

Page 1. “Studies have shown that municipal landfills can leak detectable concentrations of mercury and, in a recent study, various mercury species were found in municipal landfill gas.” It should be pointed out that the concentrations in the leachate can exceed water quality standards, and also that the mercury species in the landfill gas included organomercuric species.

Page 8. “Methylmercury’s extreme toxicity has been well documented in a number of epidemiological studies.” This statement requires a reference. What studies are being referred to? Methylmercury poisoning in Minamata Bay? Faroe Islands?

Subsection I-C-1 on *Health Effects* is poorly referenced. For this and the following discussion on toxicology in Section 2, the authors could examine Goyer (1996) or Magos (1997).

In subsection I-C-2 *Public Health*, only Minamata Bay is mentioned. This was a mass industrial poisoning where raw methylmercury was dumped into a tiny bay where the affected population mostly ate fish and shellfish. Using this historic incident, which occurred a half century ago in post-war Japan to represent the current health issues associated with environmental mercury concentrations in California is questionable. Moreover, there is no mention of in this section of current and relevant epidemiological studies such as the Faroe Island or Seychelles studies, which are described in NRC (2000) repot. Although the results of these recent and ongoing studies are still a matter of some scientific debate, their findings provide a more reasonable scientific basis for concern about the chronic low-level effects of mercury in California today.

The section I-2-D-1 *Bioaccumulation and Biomagnification* includes many misconceptions. Organic monomethylmercury (MMHg) is produced from inorganic Hg(II), (Bertilsson and Neujahr 1971; Imura et al. 1971), a process thought to be carried out primarily by sulfate reducing bacteria in anoxic sediments (Compeau and Bartha 1985; Gilmour et al. 1992). The general reason for bioaccumulation is poorly described, and this seems inappropriate given the DTSC’s claim that the proposed regulations are based, in part, on the fact that mercury is a bioaccumulative chemical substance. This phenomenon is fairly well described in general terms by several authors in several works, including Boudou and Ribeyre (1997). The importance of fish absorbing MMHg across their gills is far less important than their dietary MMHg intake.

In subsection I-2-D-2 *Persistence*, the authors could better develop the concept of the "persistence" of mercury. The authors could mention exactly what is encompassed by the biosphere, and then show how the extraction of resources from the Earth, including mercury ore, increases the amount of mercury in the biosphere. Instead, the structure of the section is rather choppy, and seems only to hint at these ideas.

Section 2: Mercury's Chemistry and Toxicology – Human and Environmental Hazards

The discussion of mercury's chemistry and toxicology within this section, as well as elsewhere in the *Mercury Report*, appears to suffer from efforts to briefly summarize this complex information and present it in a form that is readable to a wide audience. [Again, I suffered from the same constraints in the preparation of this review.] As a consequence, this section contains numerous statements that are circumspect or simply incorrect. In addition, there is a great deal of information that is irrelevant to the DTSC's objectives (e.g., "Gallium and Cesium [*sic*] are the only other metals that are liquids at room temperature" – this is also another incorrect statement).

Those difficulties could be circumvented by more effectively synthesizing information from the recent report by the National Research Council (NRC, 2000), *Toxicological Effects of Methylmercury* [The *Mercury Report* incorrectly references the "National Academy of Scientists" rather than the "National Academy of Sciences", which organized the National Research Council (NRC); and a NRC committee – not the NAS - wrote the report.]. This extensively referenced and carefully edited report provides the best synopsis of the current status of knowledge on mercury's biochemistry and toxicity, that is needed to substantiate the DTSC efforts to control mercury contamination in California.

The NRC (2000) report also specifically addresses the scientific controversies and uncertainties about what are acceptable levels of mercury exposure, notably those in fish. It emphasizes that "The contradictory findings from the Seychelles and Faroe Islands studies have made it difficult to determine an appropriate point of departure for risk assessment." This acknowledgement of uncertainty is especially important for the *Mercury Report*, because of its emphasis on the potential hazards of mercury poisoning from contaminated fish consumption.

The other principal concern with this section is, as with the previous section, its emphasis on national and global reports on the biogeochemical cycle of mercury rather than on studies of the biogeochemical cycle of mercury in California. One report from California is cited (Jones and Slotton, 1995 [I think it should be Jones and Slotton, 1996]), but it is not in a peer reviewed scientific journal or an equivalent. Therefore, in this section, the connection between the mercury problem in California and the proposed DTSC actions is limited.

Section 3: Sources of Mercury in California's Environment

In contrast to the limited direct references to the status of mercury contamination in California in sections 1 & 2, this section does provide some information. The discussion would be strengthened by adding additional citations and relying less on two references (i.e., Alpers and Hunerlach, 2000; Jones and Slotton, 1995 [*sic*]). As previously noted, one of those two references (Jones and Slotton, 1995 [*sic*]) is of limited value because it was not published in a peer-reviewed scientific journal or an equivalent. The other reference (Alpers and Hunerlach, 2000) is informative, but it is merely a USGS Fact Sheet, which is a small summary brochure, and it does not make an ideal reference.

The section could make use of atmospheric data in a report from the San Francisco Estuary Institute (SFEI, 2001).

The section could also discuss the study by Hornberger et al. (1999), which provides insights into the history of mercury deposition in San Francisco Bay.

Section 5: Waste Contribution to the Mercury Environmental Burden

Comments of this section are similar to those of the previous sections. Estimates of the waste contribution to the mercury environmental burden in California are primarily derived from simple, linear extrapolations of national estimates by the United States Geological Survey (Sznopek and Goonan, 2000) and the United States Environmental Protection Agency (U.S. EPA, 1997), presumably because there are insufficient data for California; and those first order approximations are, again, reported three significant figures. Other mercury data specific to California are included in the report, but these data are derived from "personal communications" or "gray literature" with incomplete citations (e.g., Barron, 2001), rather than from publications in peer reviewed scientific journals or their equivalents. Consequently, the DTSC effort to address the problems of mercury wastes in California is constrained by the unknown magnitude of those wastes within the state.

An associated problem with using the national assessments is that some of them are taken too literally, rather than applied to the situation in California. For example, the "Key points" of the section include statements like:

> "• From 1970 to 1986 U.S. conducted mercury mine production and imported mercury."
>
> "• From 1993 to 1998, the United States does no primary mercury mine production and uses secondary production of mercury to meet its supply needs."

More appropriate "Key points" for the *Mercury Report* would be statements of the nearly 150 year duration of mercury mining operations in California, the amount of mercury derived from that activity, and the amount of mercury now imported into the state, either for industrial uses within the state or as constituents of commercial products. Again, that

information would provide a better perspective of the historic legacy of mercury production in the state and the magnitude of mercury wastes now being added to that legacy.

The section does quantify California waste-derived air emissions. These are tabulated from data collected by the California Air Resources Board (Table 5-2), but the source of those data is not well referenced. Moreover, recent studies have demonstrated that much of the atmospheric mercury in California is derived from emissions elsewhere, as acknowledged elsewhere in the *Mercury Report*—but not in this section.

Qualifications: This review of the DTSC report was severely time constrained (i.e., the agency provided approximately two weeks for this review of their 125 page report). This limited the amount of precluded a rigorous assessment of some of the information and data sources referenced in the report; an independent peer-review of this review; and a careful editing of its content and references. Consequently, this brief review may be subjected to some of the same criticisms that it levels on the DTSC report.

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